The effects of an earthquake on rotating machinery

by Mark Gillett
ROTEK Engineering (Pty.) Ltd.
and David Crotty and Neil Hughes
Bently Nevada (U.K.), Ltd.
and Jerry Miller
Bently Nevada Corporation
and Leif Lauridsen
Bently Nevada Corporation

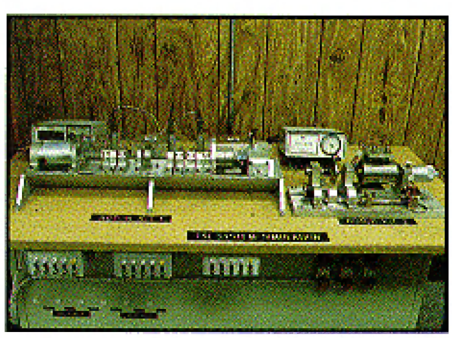
Earthquakes are part of daily life in many parts of the world. Where towns and cities have been built on the earth's natural fault lines, man has learned to adapt to the earth's motion. Even so, earthquakes can have a devastating effect on nearby communities and their associated industries. Maintaining power and other essential industries after an earthquake is extremely important for public safety. Sometimes, though, undamaged machines are shut down in an earthquake simply because the earth's motion is interpreted as rotor-related vibration. This most often occurs when seismic transducers are the only vibration measuring devices and shaft relative (proximity) transducers are not available to complete the picture.

Three types of transducers are commonly used to measure vibration on rotating machinery. One, the proximity probe, measures shaft motion relative to its mounting location. The other two types of vibration transducers, velocity sensors (or Velomitor® sensors) and accelerometers, are called seismic transducers. Seismic transducers measure absolute motion; that is, motion relative to an internal inertial reference. They are mounted on a machine's housing, where they measure housing movement.

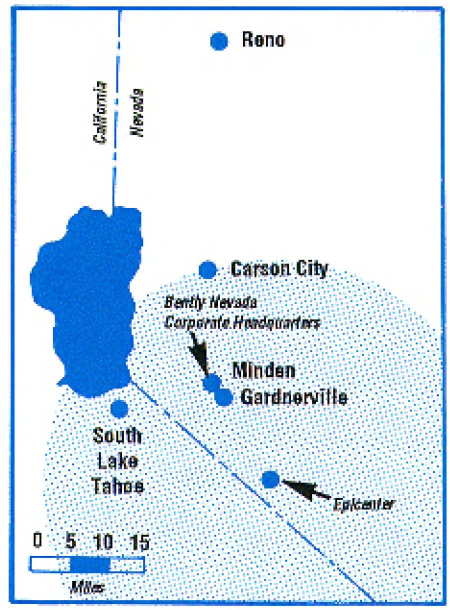
When rotors vibrate, the shaft moves relative to its bearing housing. A shaft-relative proximity probe is the only transducer that can measure rotor movement. On many machines, some of the rotor motion is transmitted to the bearing housing, causing it to move. On these machines, a seismic transducer can detect rotor-related vibration. However, when an earthquake moves a machine, both the machine's rotor and housing may move together. In this case, shaft relative proximity probes will indicate little rotor motion relative to the bearing housing.

In contrast, seismic transducers indicate only that housing motion has occurred. Monitoring equipment that uses seismic transducer motion to indirectly indicate rotor motion can interpret this as a rotor-related fault. If the motion is large enough, the monitoring equipment may initiate a machine shutdown, although no rotor-related vibration has occurred.

We recently had an opportunity to observe these effects ourselves. In the early morning hours of 12 September 1994, Bently Nevada's Minden, Nevada headquarters was rocked by an earthquake. The 6.3 magnitude earthquake's



RK4 Rotor Kit Installation



epicenter was approximately 30 km (19 miles) away. (Each point on the scale means 30 times more energy than the preceding point).

In the Bently Nevada Product Demonstration Room are RK4 Rotor Kits, small rotating machines used to provide data to online diagnostic equipment. One RK4 is connected to a permanently-installed 3300 Vibration Monitoring System that is linked to a Transient Data Manager®2 (TDM2) System which continuously monitors & stores vibration data. It is fitted with both shaft-relative proximity probes and seismic Velomitor transducers.

After the earthquake, we generated graphs from data that the TDM2 System acquired during the earthquake. These graphs clearly show the difference in response between shaft-relative and seismic transducers.

The data for the graphs in Figures 1 and 2 came from a seismic transducer

mounted vertically on the RK4's housing. Figure 1 is a trend plot, trending overall seismic vibration data from before the earthquake occurred through a series of aftershocks. It shows that, prior to the earthquake, steady state vibration averaged 5μm (0.2 mils) peak to peak (pp). When the earthquake occurred, vibration increased to at least 127μm (5.0 mils) pp. The TDM static data port, which provided data for this plot, is limited to the monitor full scale amplitude.The Danger Alarm level on this 3300 Monitoring System channel was set at 64 μm (2.5 mils) pp, so the 3300 Monitoring System went into Danger Alarm. The aftershocks which followed also sent the 3300 Monitor System into Danger Alarm.

Figure 2 shows the timebase waveform during the earthquake from the TDM's dynamic data port, and, consequently, the actual housing vibration. Notice the vibration's low frequency component and its amplitude. At nearly 500μm (20 mils) pp, its amplitude is almost four times greater than that shown in the Figure 1 trend plot.

Contrast these graphs with the corresponding graphs in Figures 3 and 4, which were generated from shaft relative proximity probe data. Figure 3 is a trend plot for the same interval as in Figure 1. The huge vibration spikes in Figure 1 are barely evident here! Figure 4 is a timebase plot taken as the earthquake occurred. TDM2 freezes dynamic data upon Alert and Danger events, so it was easy to recall the stored data. The large, low-frequency component seen in Figure 2 is also gone. *These plots show that, although the seismic transducers indicated large motion, there was no abnormal, rotor-related vibration during the earthquake!*

The RK4 Rotor Kit suffered no damage; the proximity probe, by reporting little shaft-relative motion, faithfully represented this. However, the seismic transducer reported large motion that, in the absence of other data, was seen as high machine vibration. This caused a Danger Alarm that, in the case of an actual machine, could have initiated a shutdown.

When an earthquake causes a monitor to go into alarm on high machine vibration, diagnostic information from that event is crucial. If no information, or information from seismic transducers only, is available, internal inspection prior to restarting the machine is very likely the operator's only option. Such an inspection could take days, depending on the machine's size. This could cause a process shutdown, leading to production losses. Therefore, it is important to recognize the limitations of seismic transducers.

We would like to hear of experiences that Orbit readers have had with machine vibration response in earthquakes. Please fax or mail the Orbit Editor, at the address listed in the front of this magazine or fax (702) 782-9337. ■

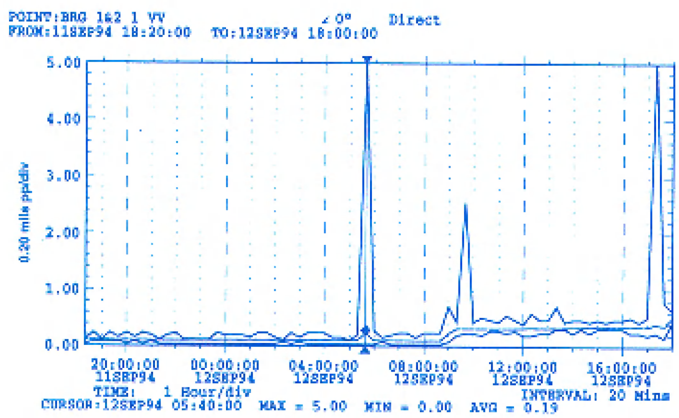


Figure 1

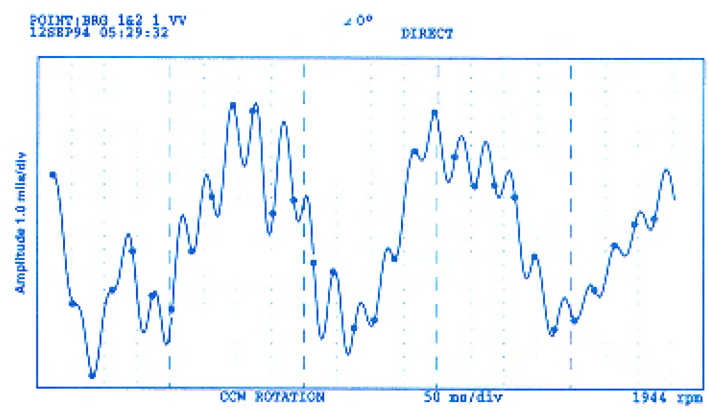


Figure 2

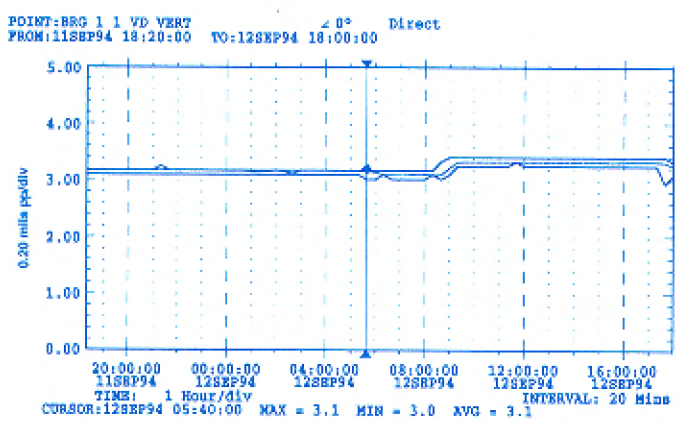


Figure 3

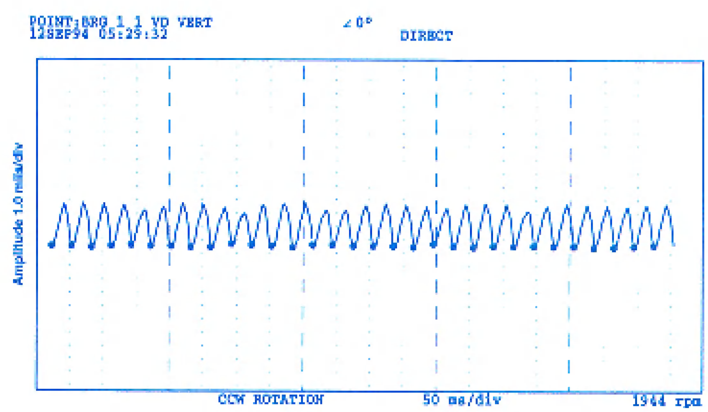


Figure 4